



NASA Goddard Space Flight Center's Contribution to Invasive Species Monitoring

Jeff Pedelty and Jeff Morisette

*NASA Goddard Space Flight Center
Greenbelt, Maryland*

HQ site visit
18 March 2004



Presentation Outline

- Overview of invasive species work with USGS
- GSFC activities/objectives
- Highlights – statistical modeling, parallel computing, incorporating MODIS data, and compiled data sets
- Plans/Future directions



Invasive Species

A Top Environmental Issue of the 21st Century ...



Economic Costs:

- *\$137+ Billion / Yr*

(Pimentel, et al. 1999; NISRC Management Plan, 2001)

Environmental Costs:

- *Decreased biodiversity, ecological services, etc.*

Human-Health Costs:

- *West Nile Virus, Malaria, etc.*

Agricultural Costs:

- *Crop pathogens, hoof-and-mouth, mad cow disease*

Notorious examples include:

Dutch elm disease, chestnut blight, and purple loosestrife in the northeast; kudzu, Brazilian peppertree, water hyacinth, nutria, and fire ants in the southeast; zebra mussels, leafy spurge, and Asian long-horn beetles in the Midwest; salt cedar, Russian olive, and Africanized bees in the southwest; yellow star thistle, European wild oats, oak wilt disease, Asian clams, and white pine blister rust in California; cheatgrass, various knapweeds and thistles in the Great Basin; whirling disease of salmonids in the northwest; hundreds of invasive species from microbes to mammals in Hawaii; and the brown tree snake in Guam.

*As many as 50,000 now,
hundreds new each year ...*



Federal Government Response



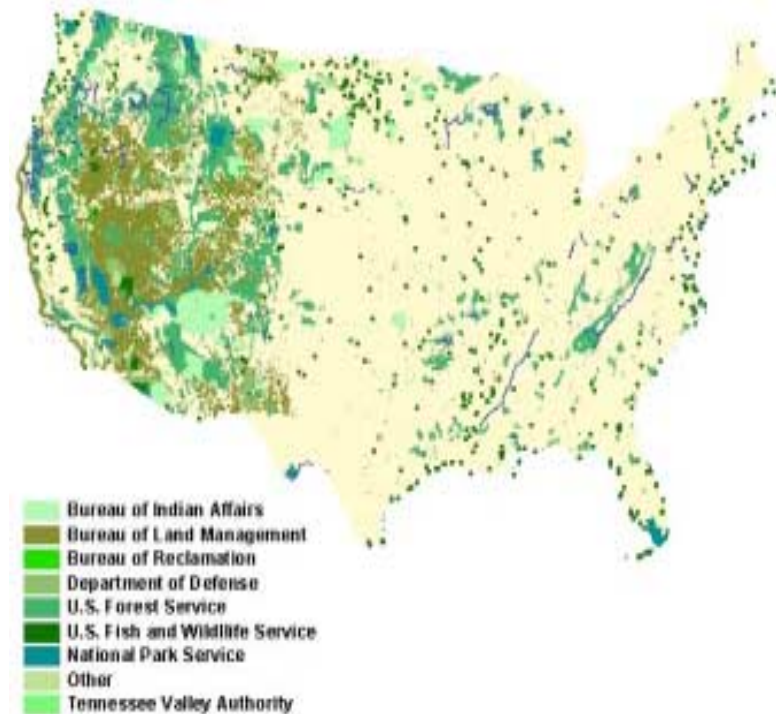
National Invasive Species

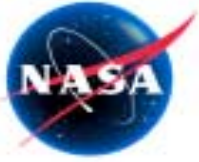
Council (EO 13122 - 1999)

- *Co-Chaired by Departments of Agriculture, Commerce, and Interior*

USGS has a lead role in dealing with invasive species science in natural and semi-natural areas

- *Responsible for measurement, management, and control on all Department of Interior and adjacent lands ...*





USGS National Institute of Invasive Species Science



USGS Biological Resources Division
(BRD) laboratory

Located at USGS's Ft. Collins
Science Center

New facilities opened Aug '02

Director, Tom Stohlgren

Many current / future partners ...



**“Grand Challenge: Biodiversity and Ecosystem
Functioning”** with special emphasis on invasive species ...
*NRC Committee on Grand Challenges in
Environmental Sciences, 2001*

“Needed: A National Center For Biological Invasions”
Don Schmitz and Dan Simberloff
Issues in Science and Technology, Summer 2001



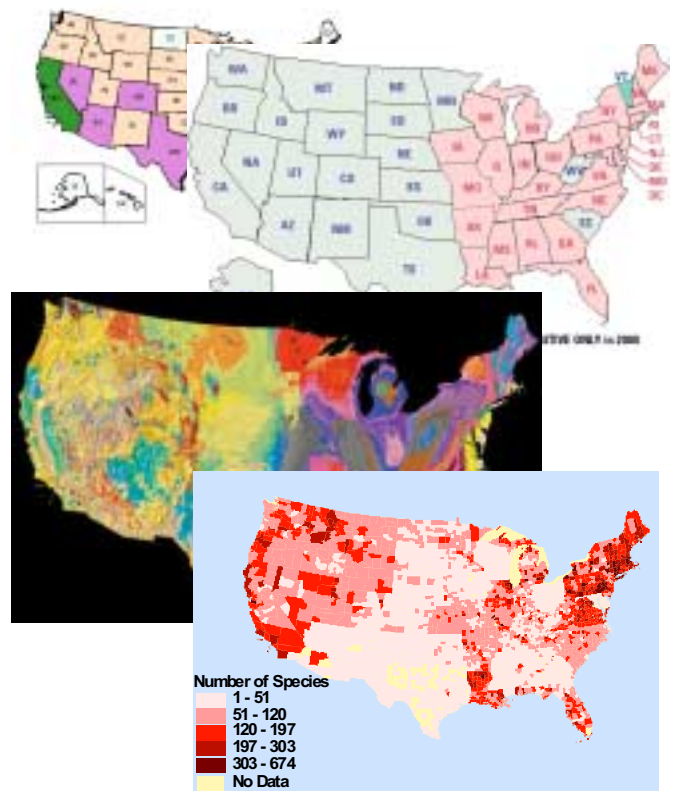
USGS Science / Client Needs

On-demand, **predictive** (in space and time) landscape- and regional-scale models and maps for biological invasions

- *Pick any point, land management unit, county, state, or region and determine the **current** invasion, and vulnerability to **future** invasion by species.*
- *Pick any species or group of species, and get **current** distributions, **potential** distribution and rate of change, each with estimates of uncertainty.*

Data integration and sharing

- *Comprehensive information on control efforts and cost. Share early detection data, control strategies, local expertise. Help public and private land managers.*





Science Questions

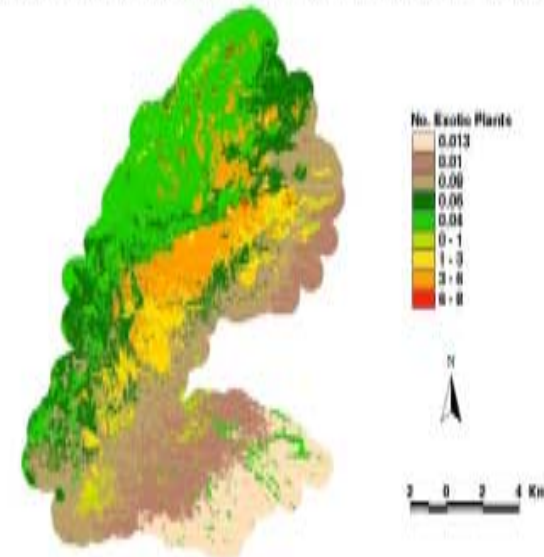
What are the biotic and abiotic factors determining species distributions at local and landscape scales?

Where are local concentrations of endemism, richness, abundance, and biomass?

What processes drive habitat and community dynamics?

How do invasive species interact with other environmental changes?

Predicted Spatial Map for Number of Exotic Species Richness with Mapping Unit of 30 Meters at Cerro Grande Wildfire Site, New Mexico.



Model Significant Variables:
UTM-X, UTM-Y, Native Plants, TM-Band (4),
Vegetation Index (Bands 5/4, 4/3, NDVI), and
TM-Tasseled Cap (Band 5); with $R^2 = 58.2\%$



Why this is a difficult challenge

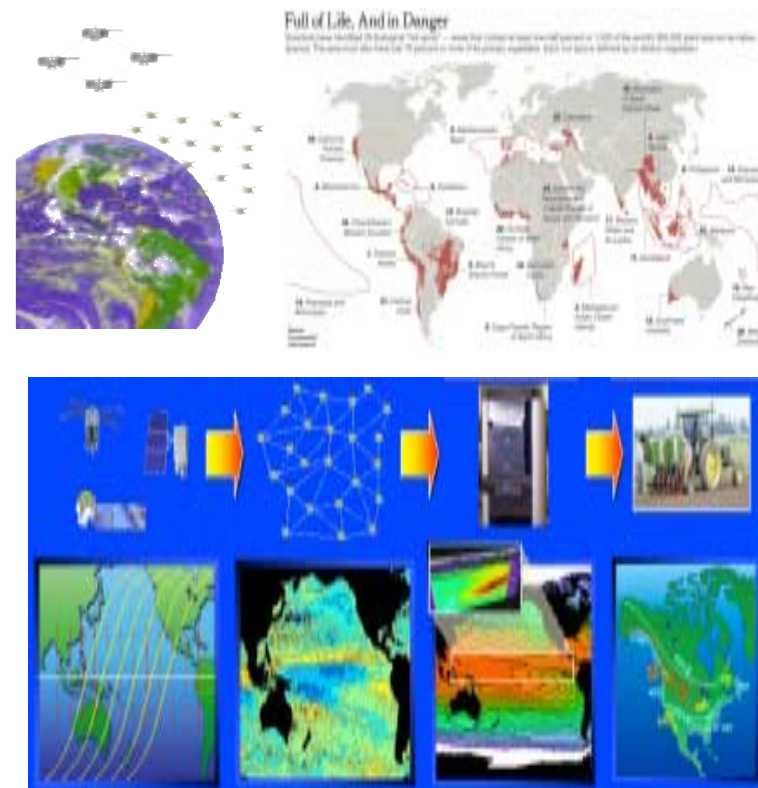
High-resolution, in space and time, is critical but “expensive”

Biodiversity “hotspots” play a critical role in the biosphere ... we must be able to adaptively span global and local scales

Early detection essential for rapid response and effective management

Quantifying pathways of introduction essential for cost/benefit guidance for eradication and control – requires more than remotely sensed data

Modeling involves large amounts of data with inherent spatial structure





National Invasive Species Forecasting System (ISFS) *



Research funded by
NASA's Earth Science Enterprise

- ***Terra and Aqua Science Applications***

Value Added Products from MODIS Time-Series Data Sets to Support DOI/USGS Invasive Species Management
(Morissette, Pedelty, Schnase, & Stohlgren)

- ***Interdisciplinary Science***

Fingerprinting Native and Non-native Biodiversity in the United States
Phase I – The Western US
(Stohlgren, Schnase, Morissette, Pedelty)

- ***ReaSON CAN***

(Schnase, Smith, Stohlgren)

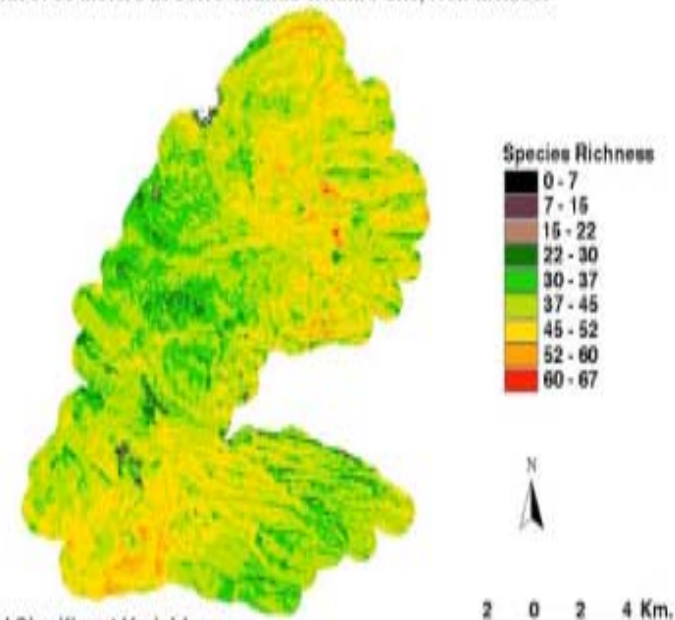
- ***Carbon Cycle Science Applications Program***

Predicting Regional-Scale Exotic Plant Invasions in Grand Staircase-Escalante National Monument
(NASA YS/YO NRA - Schnase, Smith, & Stohlgren)

- ***Computational Technologies Program***

Biotic Prediction: Building the Computational Technology Infrastructure for Public Health and Environmental Forecasting
(NASA YS CAN - Schnase, Smith, & Stohlgren)

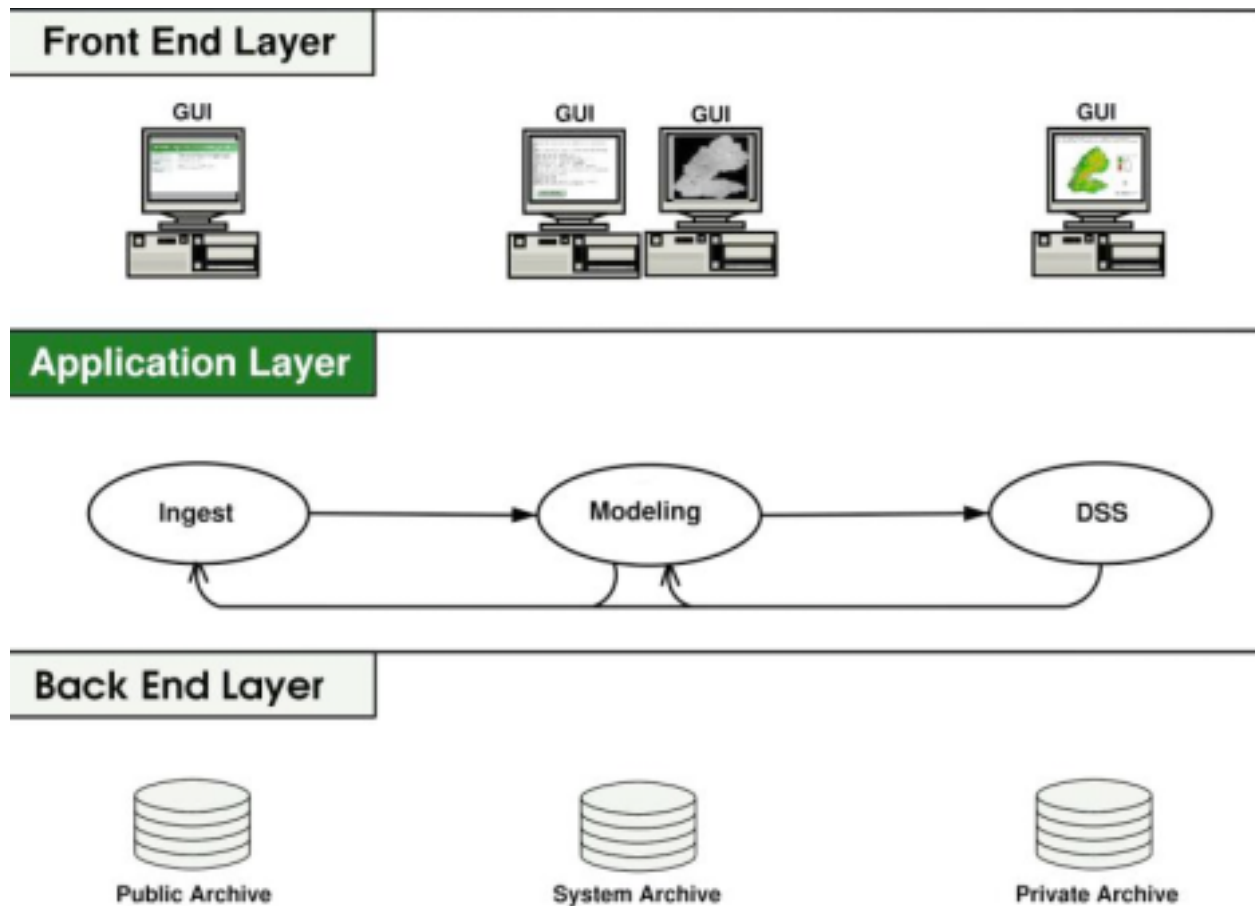
Predicted Spatial Map for Total Plant Species Richness with Mapping Unit of 30 Meters at Cerro Grande Wildfire Site, New Mexico.



Model Significant Variables:
Elevation, Slope, Vegetation Index (TNDVI), and
TM-Tasseled Cap (Band1); with $R^2 = 63.9\%$.

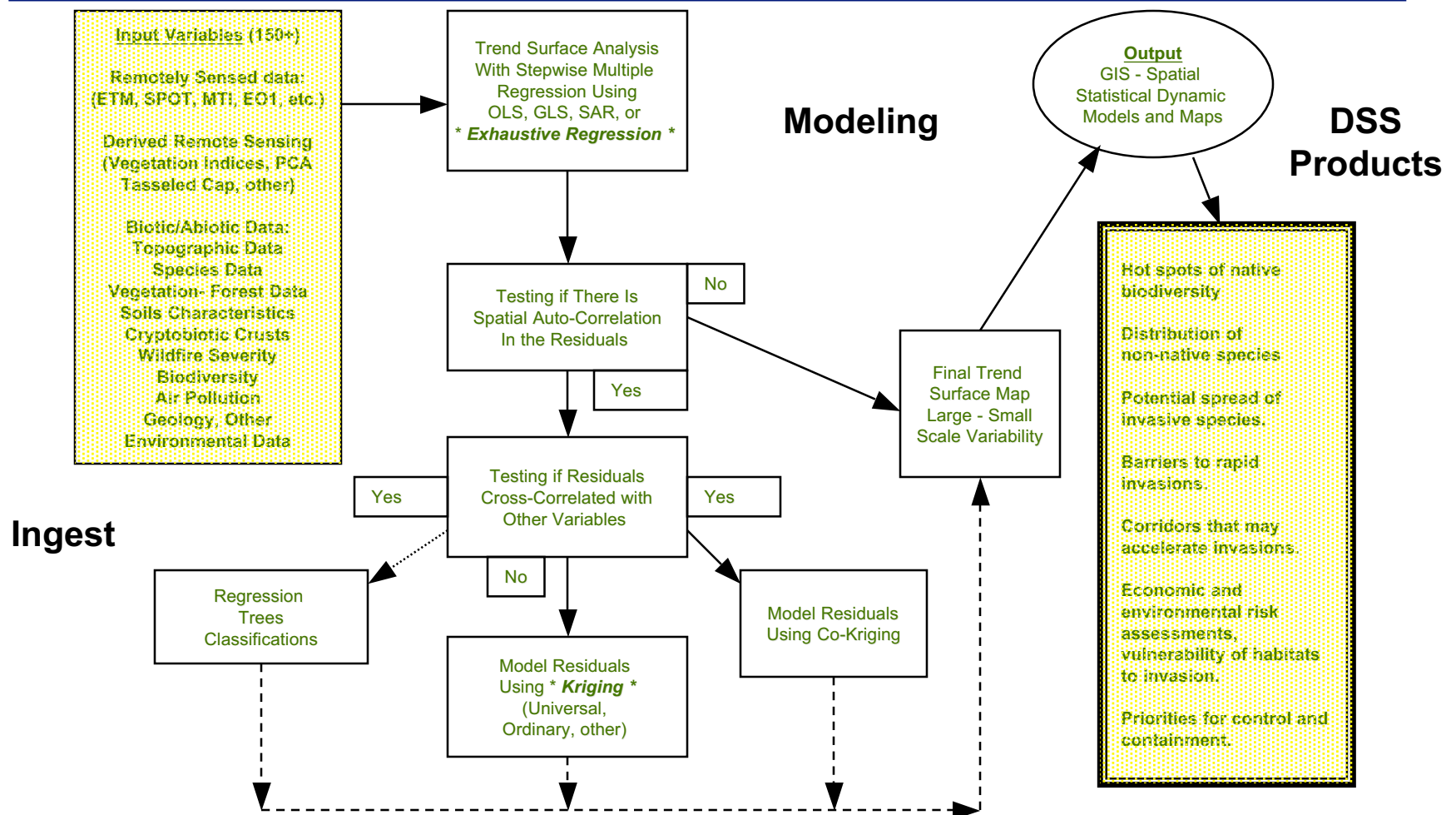


Invasive Species Forecasting System Architecture



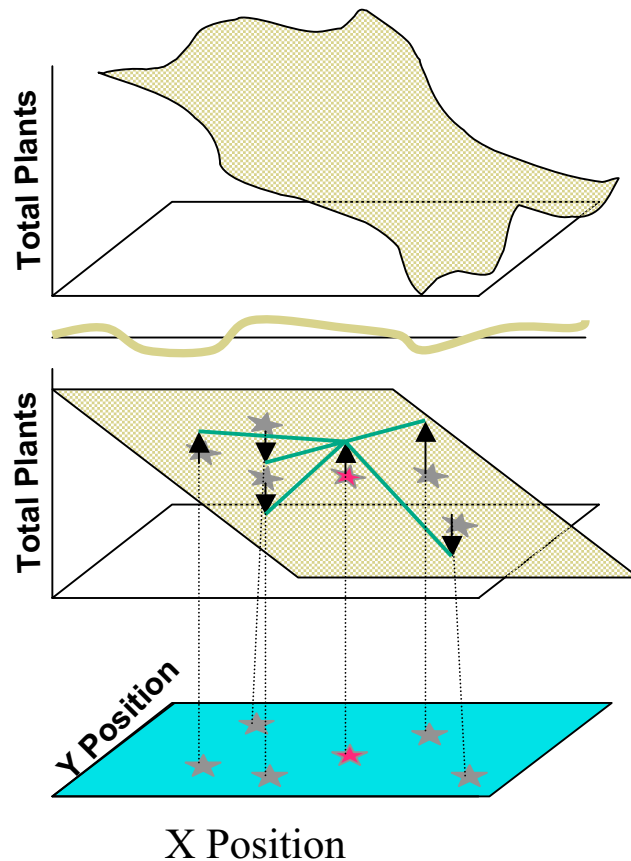


“Baseline” Predictive Modeling





Kriging residuals to account for spatially correlated errors

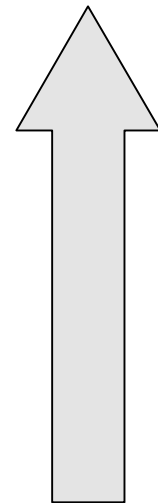


$$\text{Tot. Plant} = b_0 + b_1 \text{ ETM} + b_2 \text{ ELEV} + \text{Kriged Residuals}$$

Kriged residuals

$$\text{Tot. Plant} = b_0 + b_1 \text{ ETM} + b_2 \text{ ELEV}$$

Field measurements of plant diversity within a sample plot

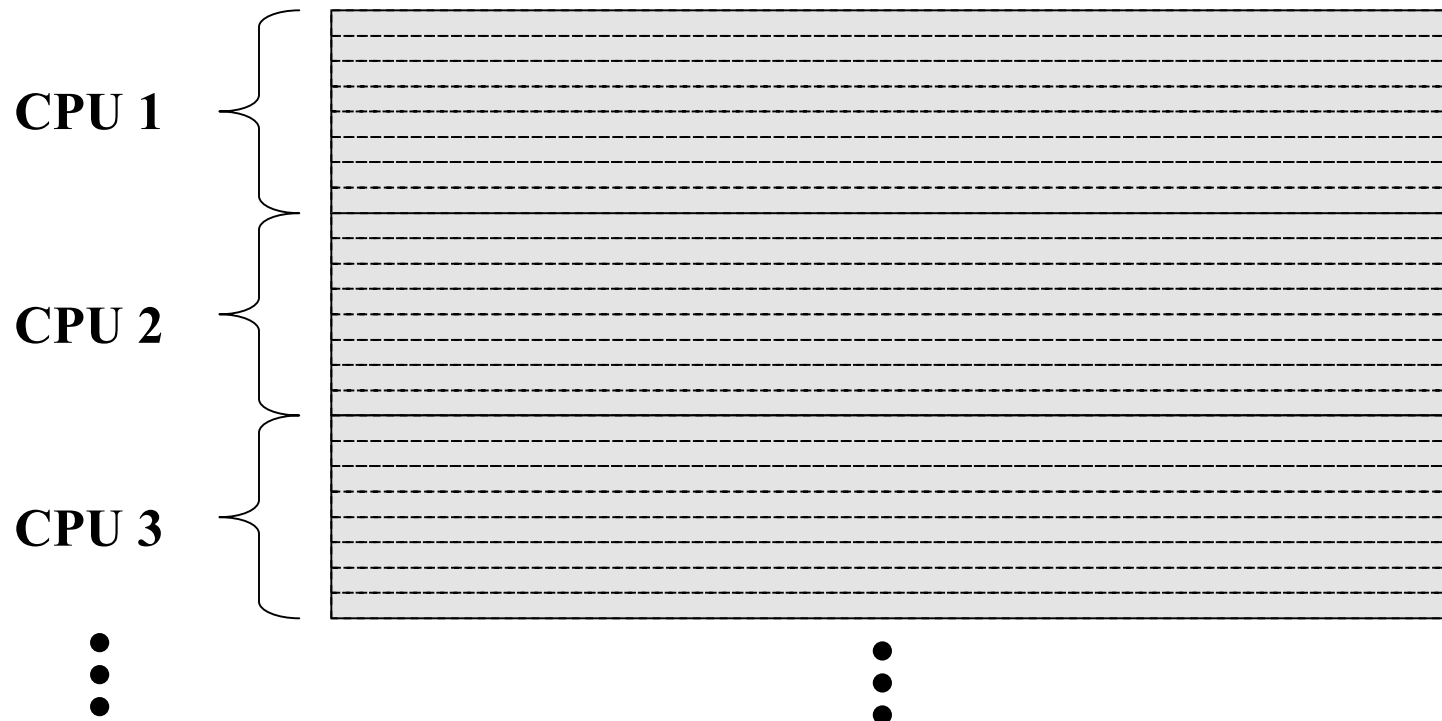




An Elegantly Parallel Algorithm

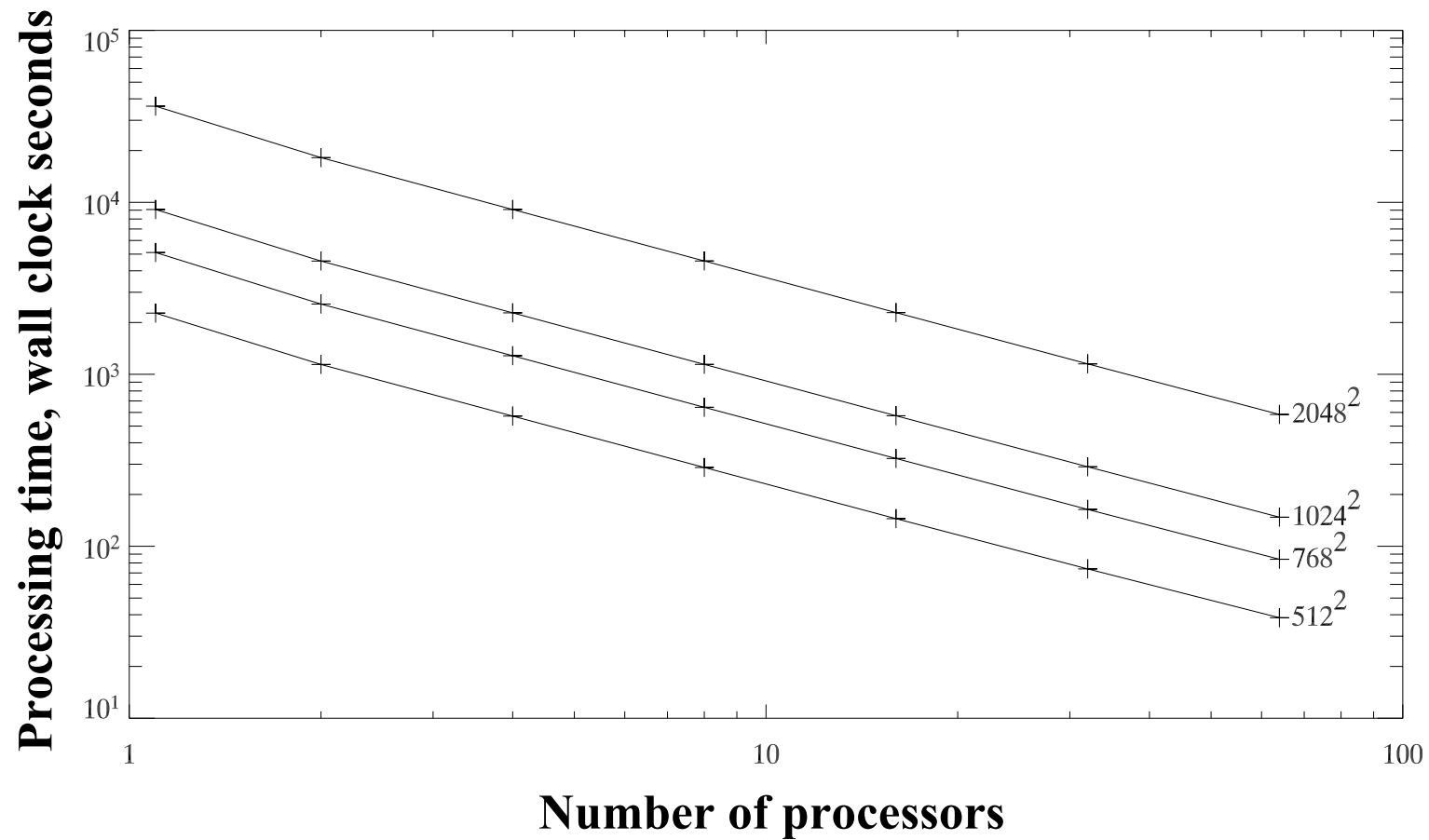
Parallelize using Domain Decomposition

Each processor gets a chunk of complete rows





Scaling Curves





Next Computing Steps

Moving to Apple Xserve G5 / Xgrid Environment

- Server node + 10 compute nodes for GSFC
 - Dual CPU G5 processors (2 GHz, 2 GB memory)
 - Gigabit ethernet connectivity
 - 3 TB Xserve RAID array
- Server + 5 nodes for USGS
- Xgrid for pool of processors computing model
- MPI also available
- New systems on order
 - Hope to receive in May





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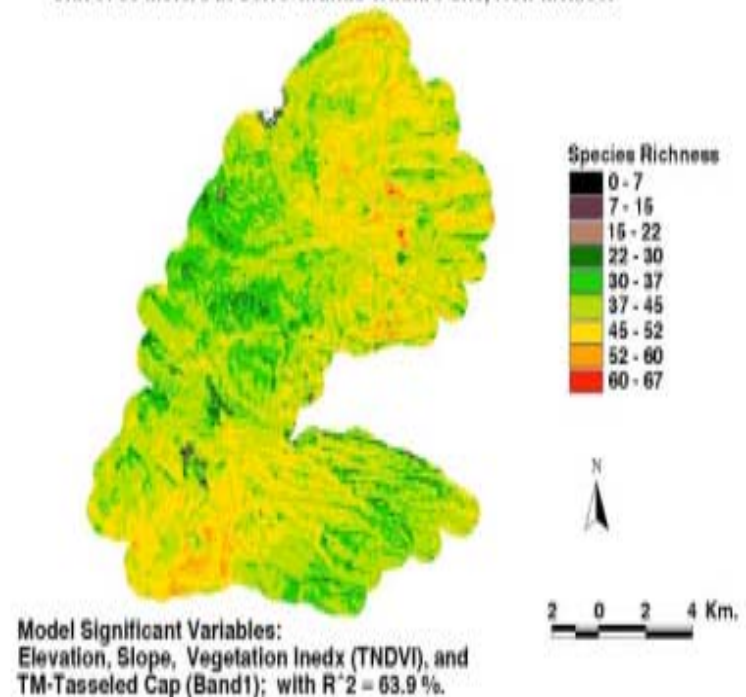
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Objectives

Address how best to exploit the MODIS time-series for invasive species forecasting.

Create a suite of value added MODIS time-series data products specifically tailored to management and policy decision-making within the National Institute of Invasive Species Science.

The derived products will be designed to feed directly into the National Invasive Species Forecasting System and related applications.



Invasive Species Roadmap

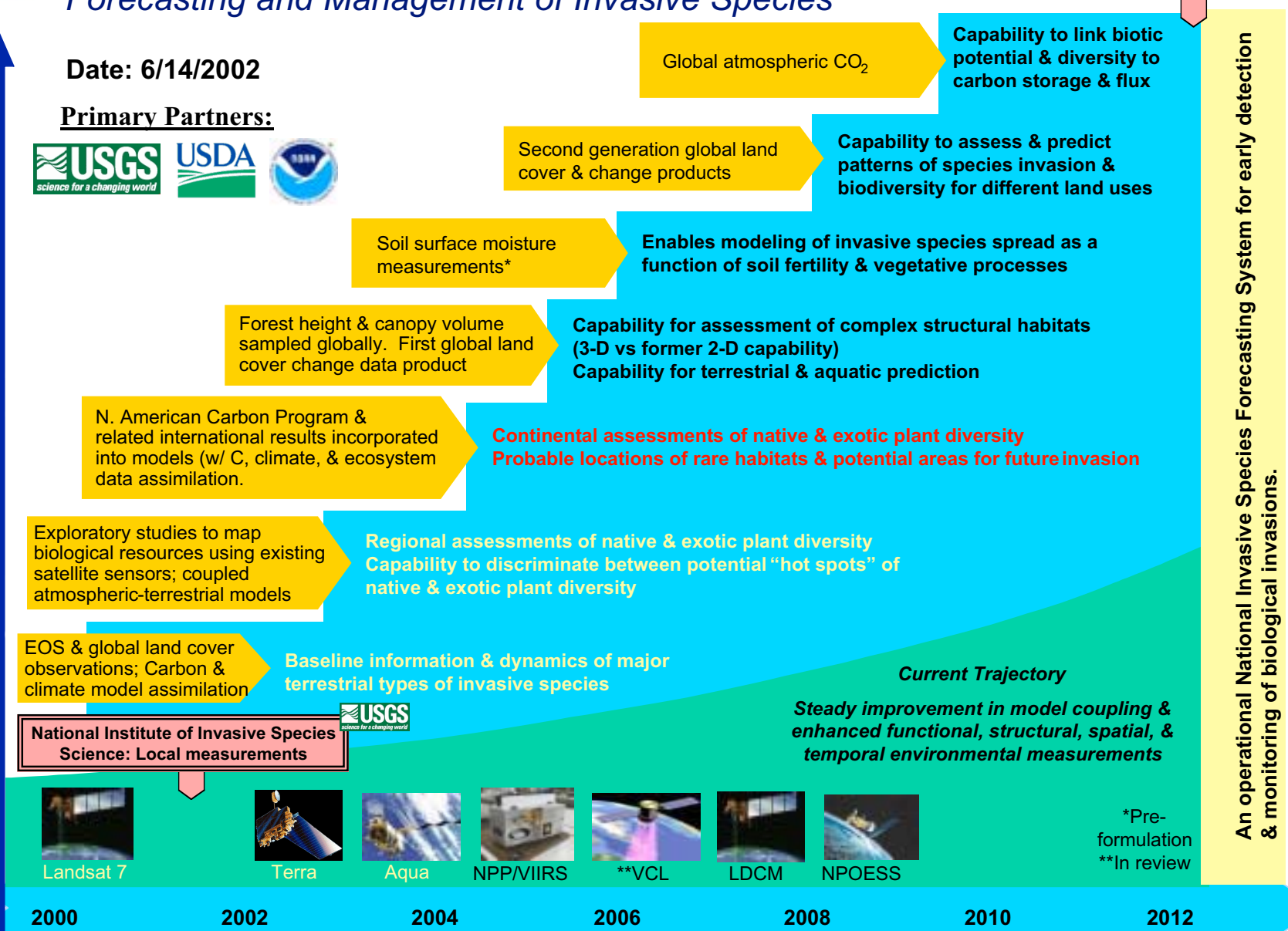
Forecasting and Management of Invasive Species

Date: 6/14/2002

Primary Partners:



National Institute of Invasive Species
Science: Regional, National, Inter,
measurements & predictions



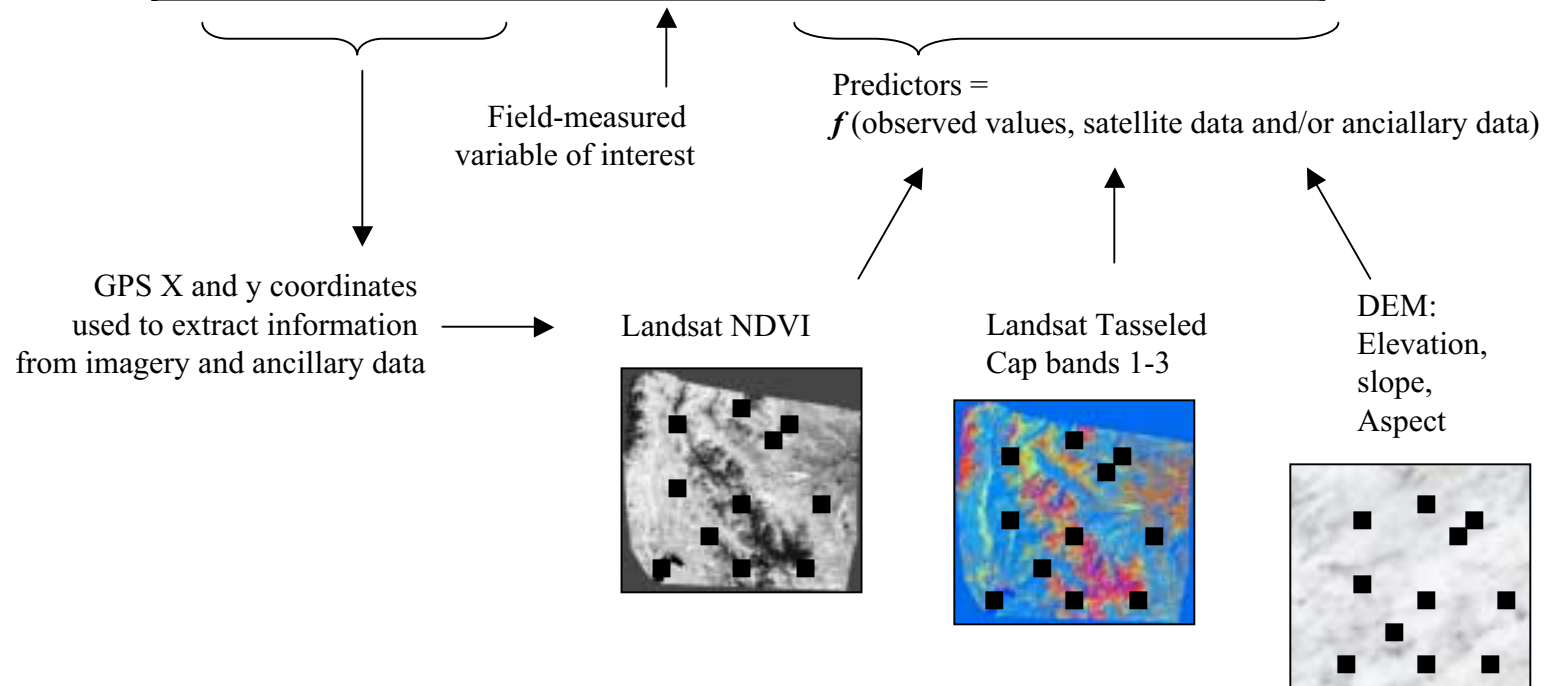
This project will make a direct contribution to the paths shown as yellow text on the blue background



Current Statistical Modeling Array

**Example
Existing Model Array:**

Lat	lon	response	Predictor 1	...	Predictor N
X_1	Y_1	R_1	X_{11}	...	X_{n1}
X_2	Y_2	R_2	X_{12}	...	X_{n2}
...

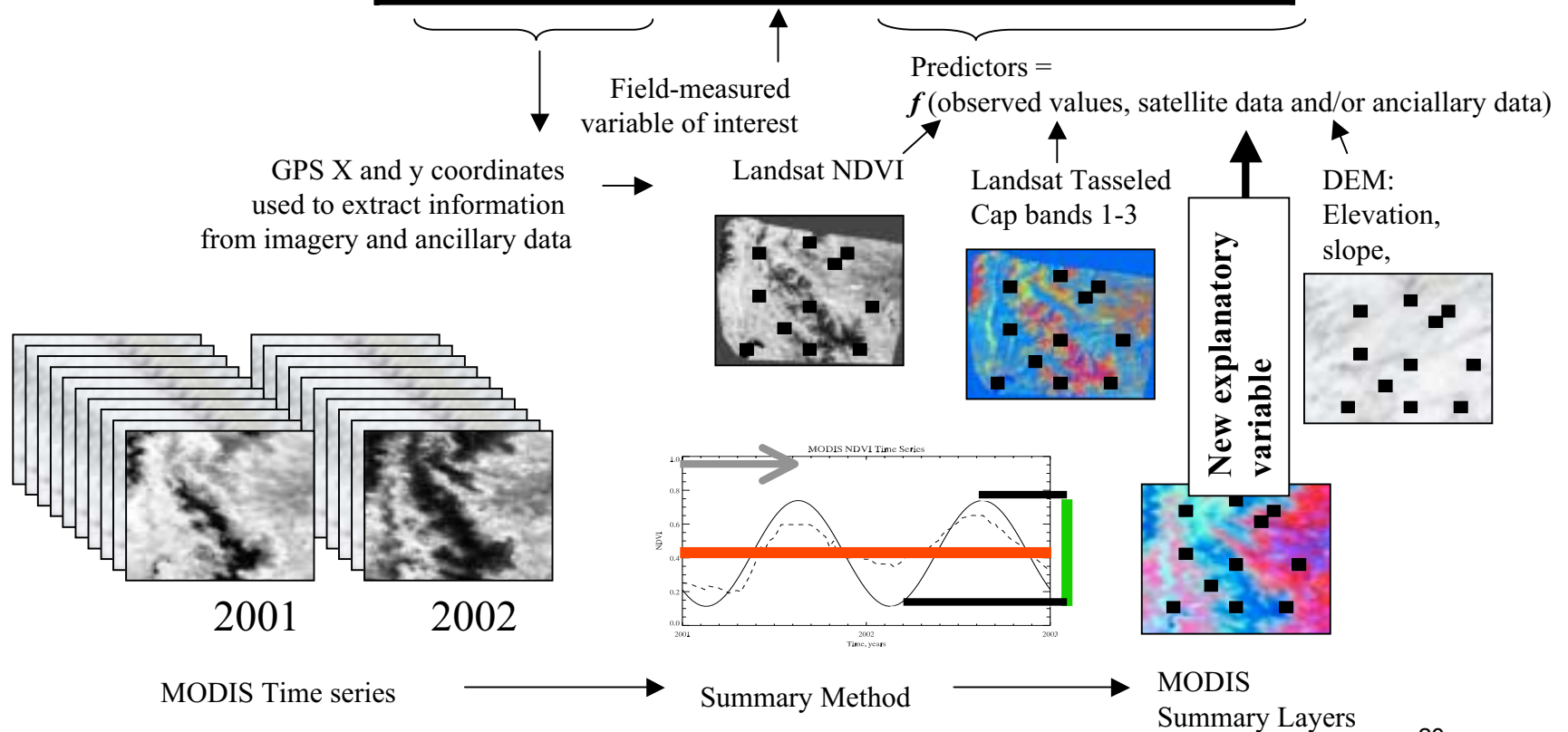




Enhanced Statistical Modeling Array

**Example
Proposed Model Array:**

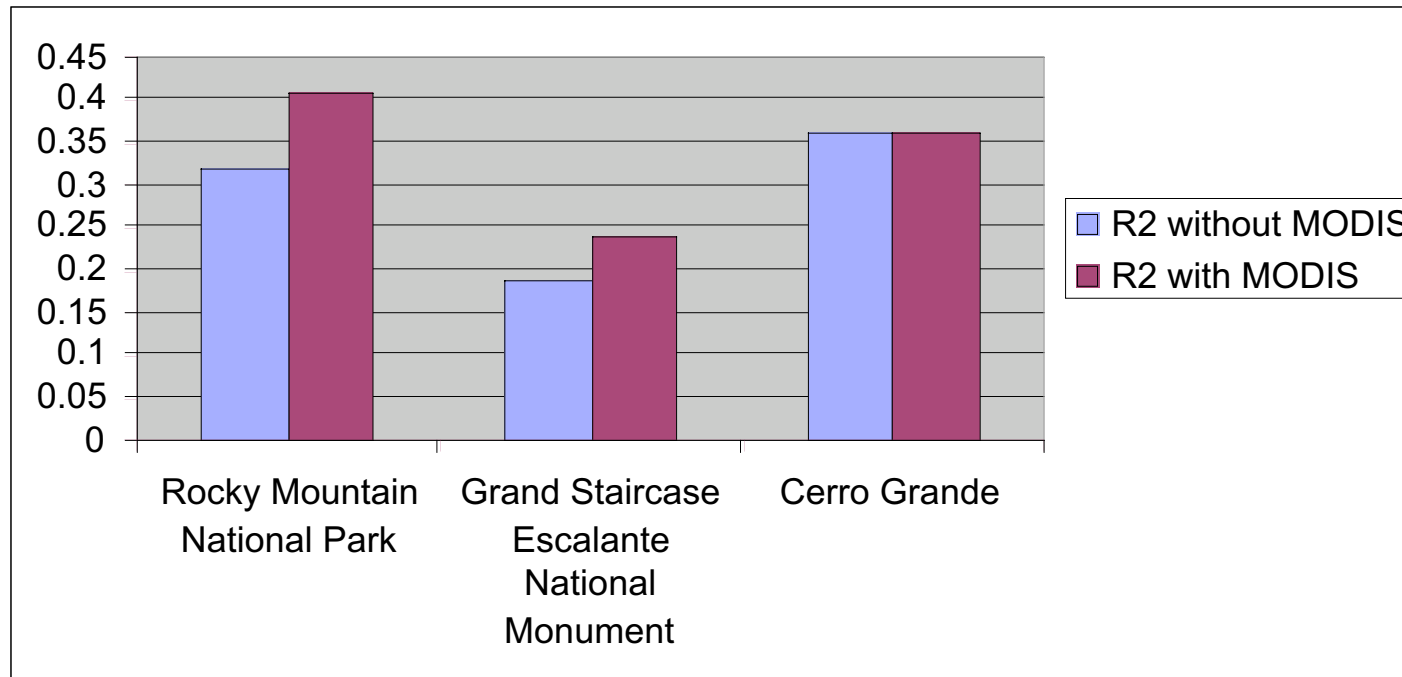
Lat	lon	response	Predictor 1	...	Predictor N
X_1	Y_1	R_1	X_{11}	...	X_{n1}
X_2	Y_2	R_2	X_{12}	...	X_{n2}
...



Mapping Invasive Species Using MODIS Times-Series Data



Quantified improvement with MODIS



R^2 values for experimental model runs on three study sites with and without the use of MODIS time-series summaries



Study Sites

Intensive Sites	State	Primary Agency	Target Issue	Target Species (or groups)
Rocky Mountain National Park (RMNP)	CO	National Park Service	Preserve native plant diversity in mountain parks	Patterns of non-native plant species
Cerro Grande Fire Site, Los Alamos (CGFS)	NM	USDA Forest Service	Vegetation restoration after wildfire in pine forests	Cover of native and non-native grass species
Grand Staircase-Escalante National Monument (GSENM)	UT	Bureau of Land Management	Grazing and plant invasions in arid ecosystems	Carbon storage of invasive cheatgrass and tamarisk
Konza Prairie, Long-Term Ecological Research Site (KP-LTER)	KS	LTER Program/ NASA	Estimating phenology and productivity in tallgrass prairie and detect woody encroachment	Rare tallgrass and herbaceous species
Extensive Site				
State of Colorado (CO)	CO	State of Colorado and	Map sites vulnerable to plant invasions	Top 5 invasive plant species throughout



MODIS product to be considered

Product Suite	Product	DAAC	RMNP	CGFS	GSENM	KP-LTER	CO
MOD09	Surface Reflectance	EDC	X	X	X	X	X
MOD11	Surface Temperature and Emissivity	EDC		X		X	X
MOD43	BRDF/Albedo	EDC	X	X	X	X	X
MOD10	Snow Cover	NSIDC	X			X	X
MOD29	Sea Ice Extent	NSIDC					
MOD13	Vegetation Indices	EDC	X	X	X	X	X
MOD15	Leaf Area Index/Fraction of Photosynthetically Active Radiation (LAI/FPAR)	EDC	X	X	X	X	X
MOD17	Net Primary Vegetation Production (NPP)	EDC	X	X	X	X	X
MOD12	Land Cover and Change	EDC	X	X	X	X	X
MOD14	Thermal Anomalies and Fire	EDC		X		X	X
MOD44	Vegetation Cover Conversion/ Continuous Fields (VCC/VCF)	EDC	X	X	X	X	X



Input data: Soil properties

Importance

- *Species habitat requirement*
- *Determinant of species range boundaries, corridors of invasion, dispersal patterns*

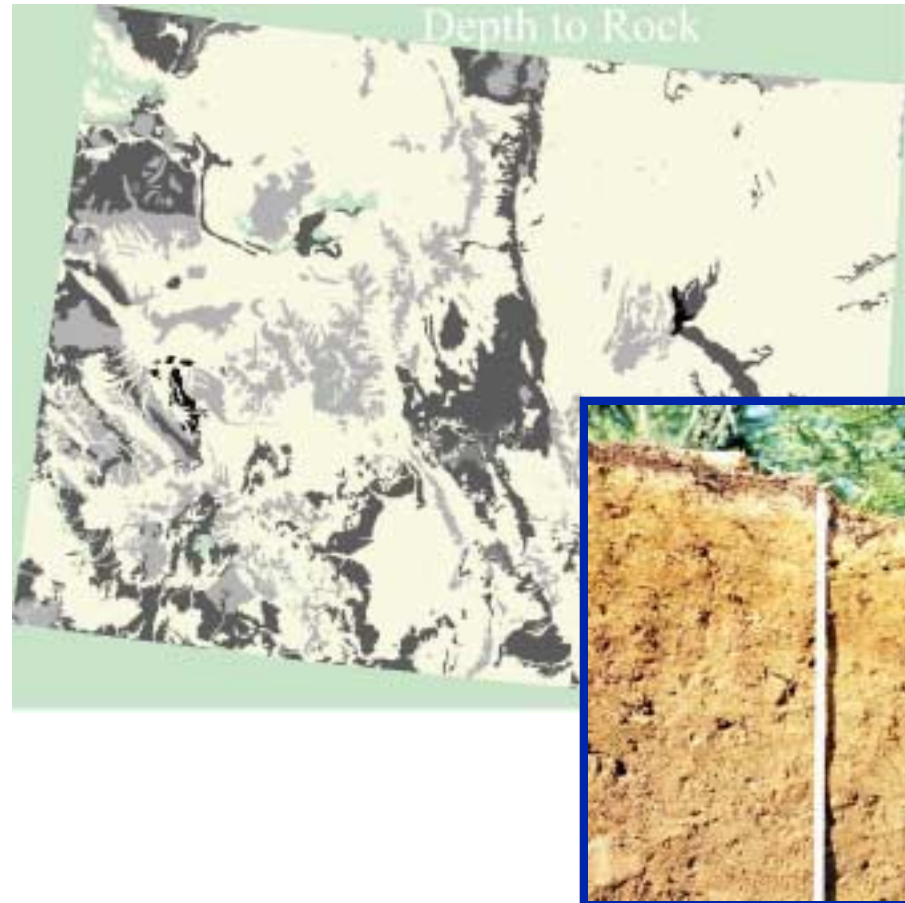
Current Sources

- *Type – STATSGO, local soil maps;*
- *Moisture – passive microwave, radar, and NIR*

Sources

- *USGS “STATSGO”*
- *<http://water.usgs.gov/lookup/getspatial?ussoils>*

Currently hold twenty soil properties raster layers at 30m spatial resolution for all of Colorado





Input data: Elevation, slope and aspect

Importance

- *Determinant of species range boundaries, corridors of invasion*
- *Influences hydrological, geological, and human processes*

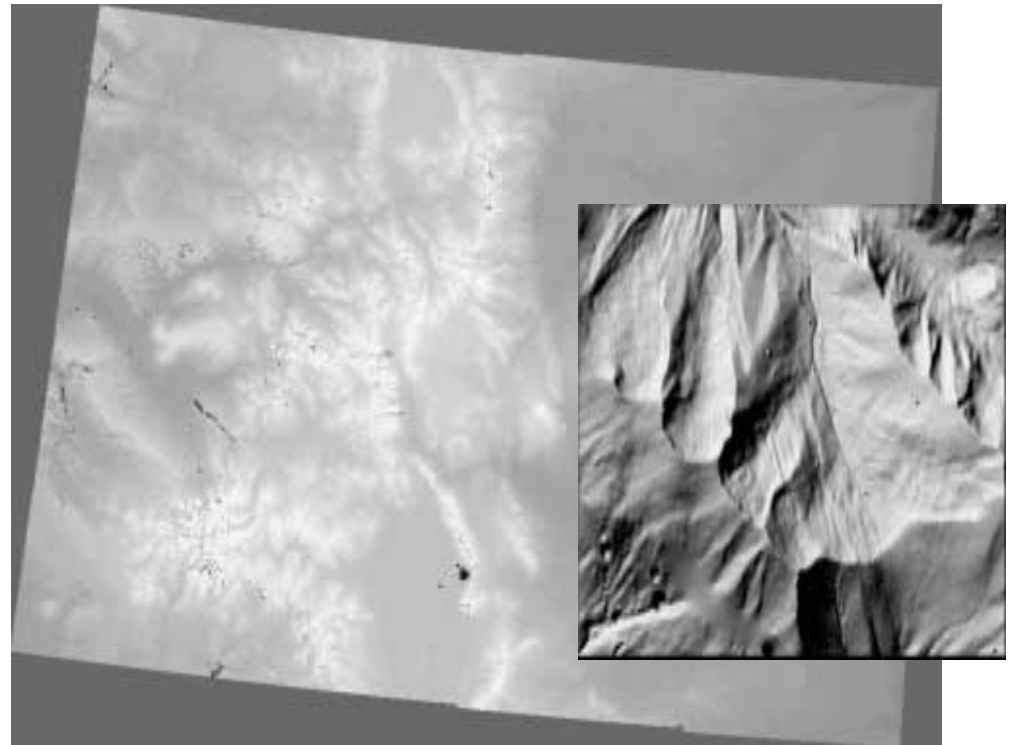
Current Sources

- *GTOPO 30; GLOBE 30 arcsec/100m; USGS/European regional models; US DEM*

Future Sources

- *SRTM (global) 30m H/30m V; High-resolution LIDAR; Military DTED2 (global)*

Currently hold Shuttle RADAR Topography Mission (SRTM) digital elevation data, at 30m spatial resolution mosaicked and clipped to the Colorado.





Input data: Vegetation signal

Importance

- Vegetation structure **the** habitat parameter for many species
- Structural complexity major driver of species richness in all environments

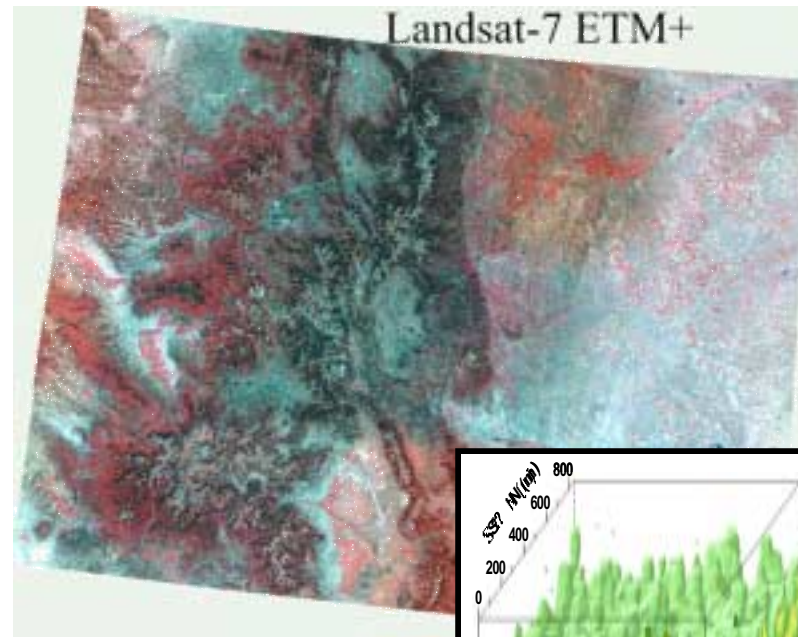
Current Sources

- Visible/Infrared – ETM+, MODIS
- SAR - Estimates of canopy texture, biomass, geometry; AVHRR – NDVI

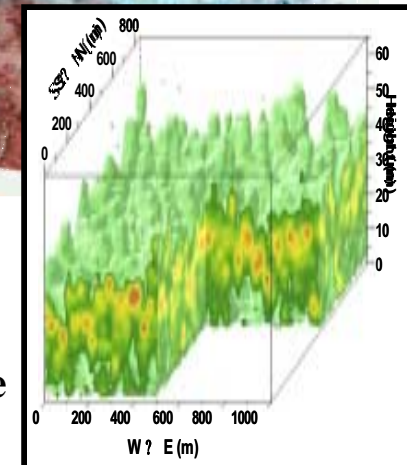
Future Sources

- LIDAR
- Vis/IR - ASTER

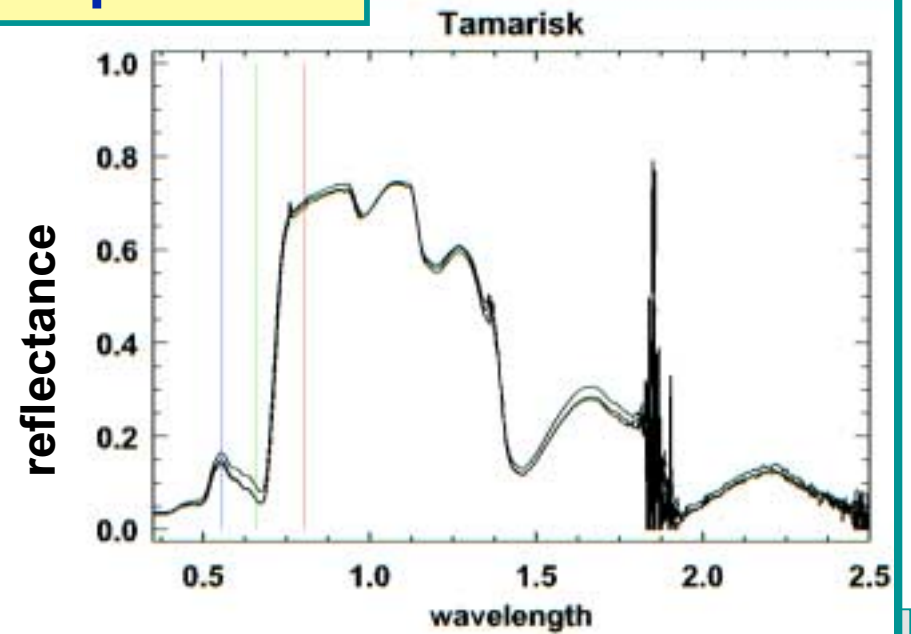
Currently hold 4 Tasseled-Cap & NDVI layers from Landsat-7 ETM+ (2000) for Colorado



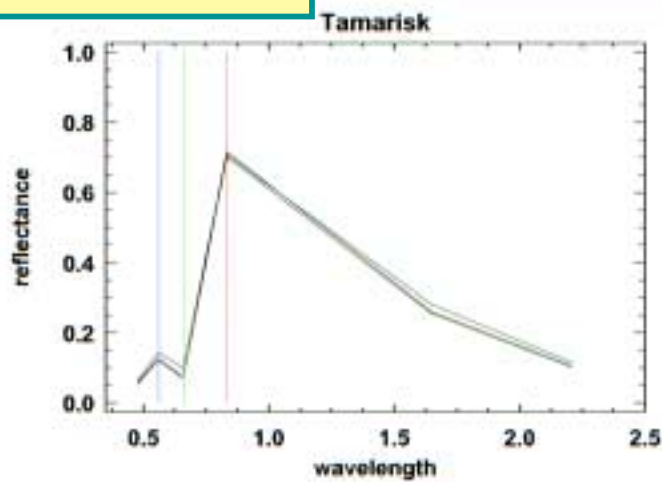
Airborne
LIDAR



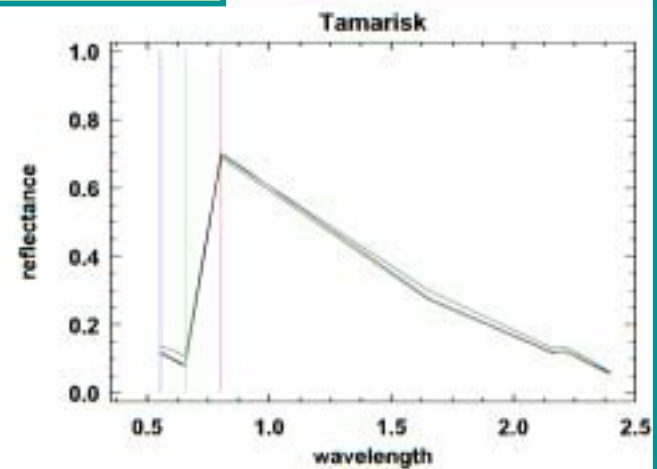
ASD Spectra...



Simulated ETM+



Simulated ASTER





Input data: Phenology

Importance

- *Plant phenology an important driver for animal species*
- *Many change habitats to track available resources*

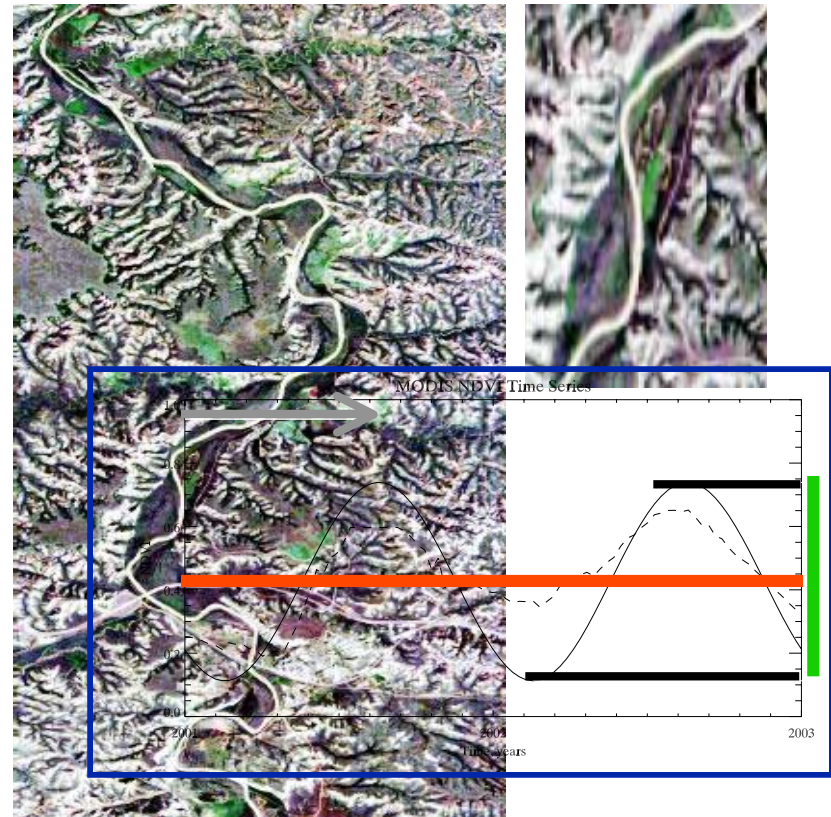
Current Sources

- *Multispectral imagery*
30m resolution several times per year
250m resolution daily

Future Sources

- *Higher temporal resolution multi-spectral*
- *Satellite-borne hyperspectral*
- *Meteorological data*

Currently hold MODIS Vegetation Index (VI) product (MOD13--16-day composite with 250m spatial resolution, ver. 004) for four years (Feb. 2000 to present) for three study sites and all of Colorado





Science plan

Short term Challenges:

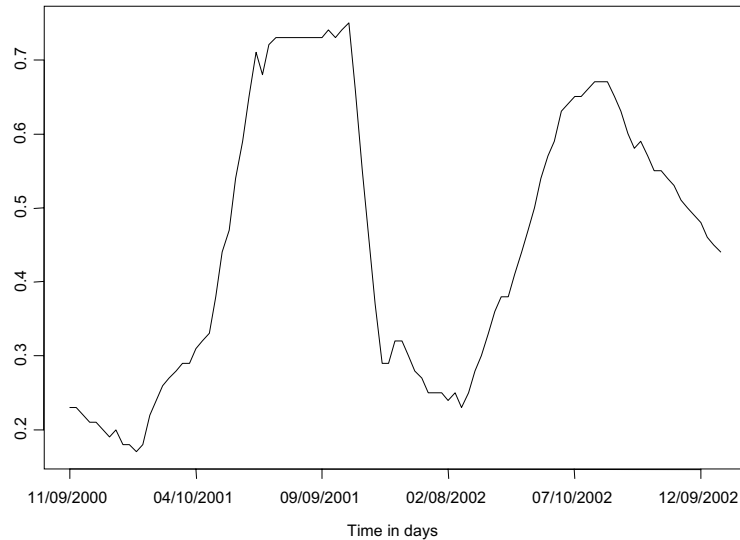
- **Strategically focus on new variables**
(MODIS time series summary methods, precipitation/meteorological data)
- **GSLIB kriging in parallel with Xgrid**
- **Combinatorial screening (in lieu of stepwise regression) for linear and logistic regression in parallel with Xgrid**

Long Range Challenges:

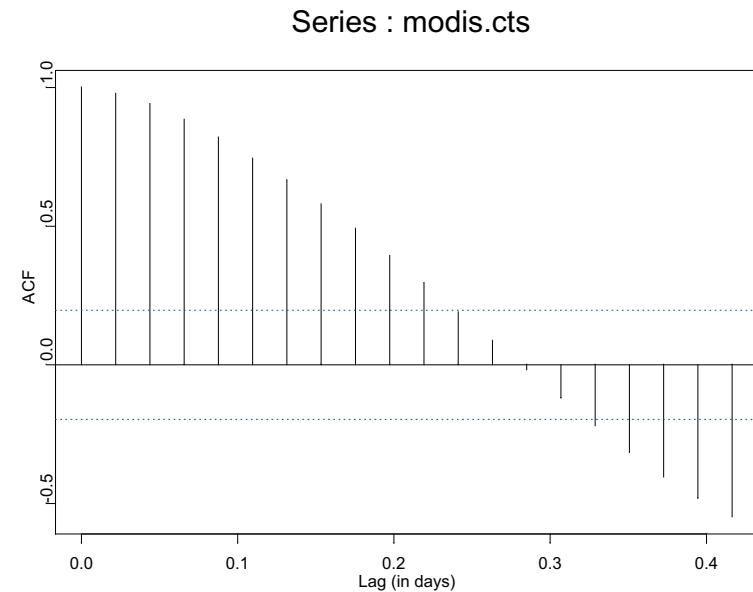
- **Code for generalized least squares for linear and logistic regression (accounting for spatial structure in model selection)**
Possible PhD student at GMU Computational Statistics Department
- **Relate empirical results to physical/mechanist model**
- **Build modeling to forecast in space *and time* based on habitat suitability/availability**



Additional data: MODIS time series



MODIS: time series



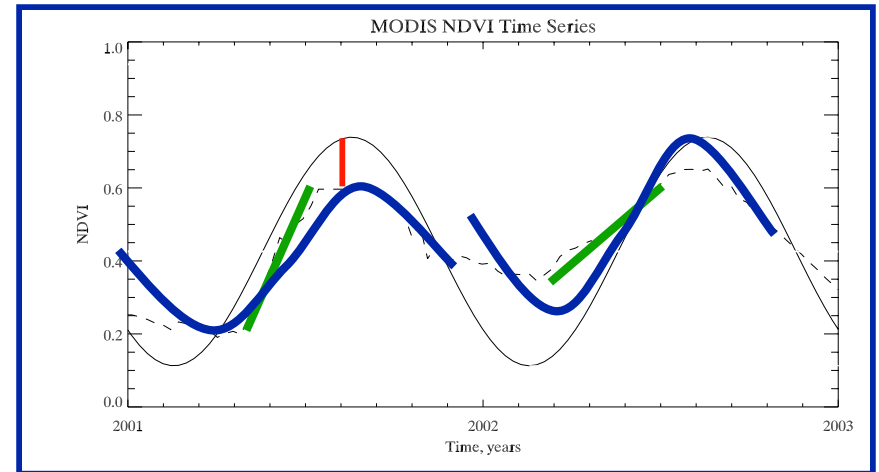
Autocorrelation function



Evaluation of Time-series Summaries

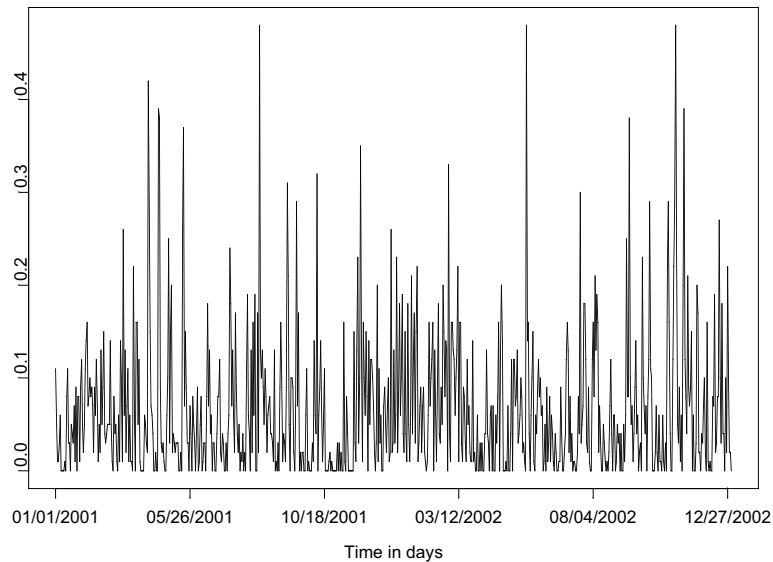
Initial tests used annual component of DFT*...other tools may be effective:

- “Anomalies”/residuals from fitted sine wave
- Date or slope of green-up
- Higher frequency components of DFT (biannual, quarterly cycles)
 - Interannual variability
- Explicit functional fits (e.g. asymmetric Gaussian of Jönsson and Eklundh 2002, *TGARS* 40(8), 1824)
- Wavelet decomposition (with J. LeMoigne, GSFC)
- Hilbert-Huang Transform
- Hyperspectral feature extraction techniques (with L. Bruce, Miss State U.)

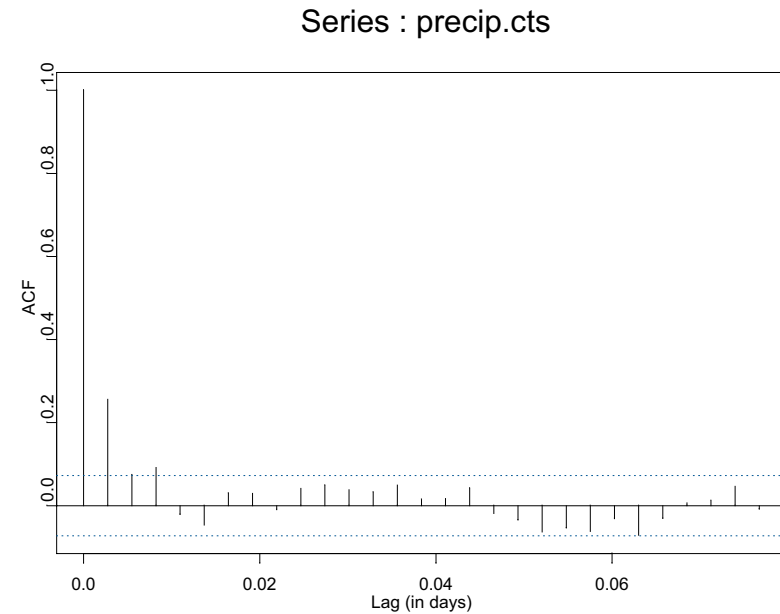




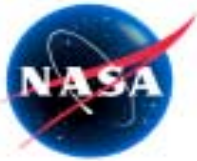
Additional data: precipitation & temperature



NOAA precipitation: time series





Autocorrelation function



Public Interface & Prototype



Invasive Species Forecasting System




- USGS Home
- Test Sites
- People
- Science
- Partners
- News

The NASA Office of Earth Science and the US Geological Survey are working together to develop a National Invasive Species Forecasting System for the early detection, identification, management, and control of invasive species on Department of Interior and adjacent lands.

The forecasting system provides a framework for using USGS's early detection and monitoring products and predictive models to process NASA and commercial data and create on-demand, regional-scale assessments of invasive species patterns and vulnerable habitats.

When fully implemented the forecasting system will provide a dynamic and flexible mechanism for generating electronic and paper maps of test spots for potential exotic species invasions.



General Information about Invasive Species:
Invasivespecies.gov details the impacts of invasive species on the species profile and outlines the response of US Federal Government agencies.

The NBI Invasive Species Information Node is a central repository for information pertaining to the identification, description, management, and control of invasive species.

Case Study: Cerro Grande Wildfire Burned Area
NASA and USGS scientists have used a prototype National Invasive Species Forecasting System model to predict the spread of invasive species at the site of the Cerro Grande wildfire near Los Alamos.

[read more](#)


The National Invasive Species Forecasting System: A Strategic NASA/USGS Partnership to Manage Biological Invasions

[download PDF](#)

Wed May 26 16:47:35 2009
Prepared by: NASA/USGS
Reviewed by: [Name]
Approved by: [Name]

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Invasive Species Information Node



[Home](#) [About NBI](#) [Current Projects](#) [Species Profile](#) [Data & Maps](#) [Inventory & Reports](#) [Control & Management](#) [Learn More](#) [Invasive Species.gov](#)

Welcome to the Invasive Species Information Node!

Invasivespecies.gov
A gateway to Federal and State invasive species activities and programs.

[Home](#) [Control](#) [Management Plan](#) [Search](#) [Contact Us](#)

Welcome to Invasivespecies.gov!

Invasivespecies.gov is the gateway to Federal efforts concerning invasive species. On this site you can learn about the impacts of invasive species and the Federal government's response, as well as read select species profiles and find links to agencies and organizations dealing with invasive species issues. Invasivespecies.gov is also the website for the National Invasive Species Council, which coordinates Federal responses to the problem.

What is an Invasive Species?

An "invasive species" is defined as a species that is 1) non-native (or alien) to the ecosystem under consideration **and** 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. (Executive Order)

What's New

- Species Profile
- Geographic Information
- News and Events
- Links and Regulations
- Resources
- Manager's Tool Kit
- Databases
- Vectors and Pathways
- Invasive Species Forecasting System

InvasiveSpecies.gsfc.nasa.gov